STATE ENGINEERING EXPERIMENT STATION

The Research Engineer

GEORGIA SCHOOL OF TECHNOLOGY

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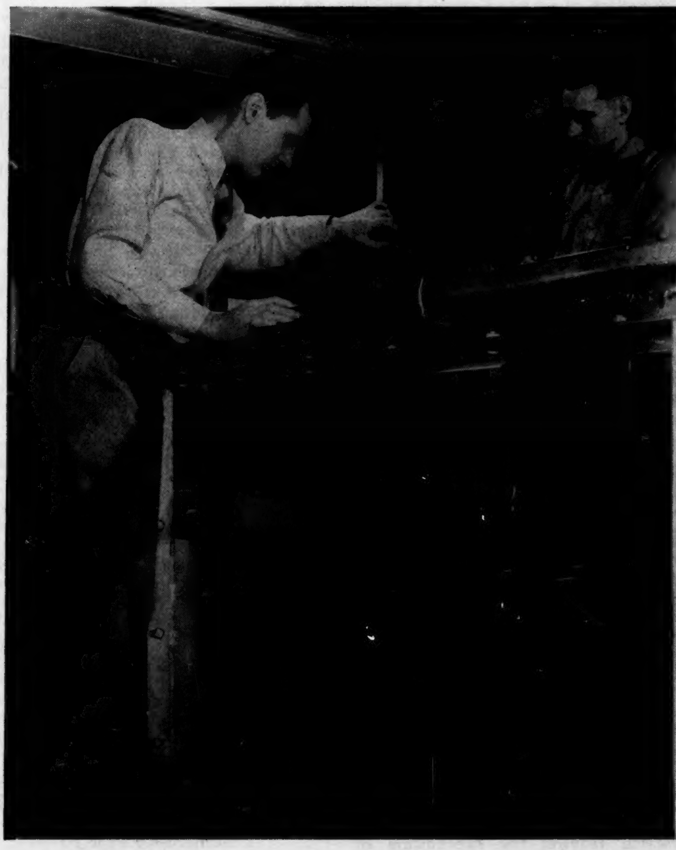

The Research Engineer

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ELECTRONIC RESEARCH AT GEORGIA TECH

The recent world conflict, with its emphasis on radar for antiaircraft defense, night bombing, submarine detection, naval warfare, and guided missiles, has served to introduce into the vernacular a term which had previously been little used except in scientific circles—electronics. Moreover, the concurrent advent of the "atomic" bomb has presented the public with a flood of information concerned with the make-up of the atom, so that the "electron" itself has made its public bow. Despite hundreds of nontechnical descriptions of these important developments, however, it is highly unlikely that any large portion of the public has any real conception of electronics, or even of the role which the electron itself plays in the science named after it.

It is true, of course, that the telegraph, the telephone, and the radio have long been commonly-accepted "marvels of the age" and that the public is aware that television is "just around the corner" from joining these inventions. "Research" on every phase of modern science and industry has been so "ballyhooed," however, that developments in those fields which rely heavily on the basic sciences have begun to be "taken for granted." Therefore, although recent Congresses seem to be reasonably aware of the need for fundamental and applied research—and the fact that such research requires the expenditure of money—there appears to be an actual danger that the publicity lately granted to scientific and engineering developments will breed a sort of uninformed contempt that might actually "backfire" on those fields which will increasingly depend on public support for their continued advancement.

Research on electronics is sufficiently multifaceted that it is difficult even for the informed to keep up with all of its phases. More and more attention is being given to such work by the manufacturers of electronic equipment and the users thereof—industry and the armed forces. As a result, electronic research is high on the list of many research organizations, among them the Georgia Tech Engineering Experiment Station.

Many of the electronic research projects undertaken here cannot be discussed for reasons of security or contractual obligations, but a description of one of them has already been published in the November, 1947, issue of this journal—Professor Honnell's article, "FM Propagation Survey of the Atlanta Area," and this issue includes Dr. Edson's excellent summary of a recently-completed project on "The Keying of Quartz Crystal Oscillators," this latter project having been sponsored by the U. S. Army Signal Corps.

While not "electronic research" in the strict sense, although certainly

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HYDRAULICS RESEARCH—ITS ROLE IN THE GROWTH AND DEVELOPMENT OF THE SOUTHEAST

By CARL E. KINDSVATER*

One of Georgia Tech's newest research facilities, the Civil Engineering Department's Hydraulics Laboratory, was described in a recent issue of THE RESEARCH ENGINEER. *In the following discussion, hydraulics research is defined and then described as a primary instrument for the development and conservation of the industrial and natural resources of the Southeast.*

In an earlier article in this journal,[1] hydraulics was defined as the "practical science which embraces the elements of fluid mechanics, fluid measurements, and hydraulic machinery." Thus, as a basic science, hydraulics is not the property of any one branch of engineering, but is instead an elemental tool for all. Progress in the broad field which it envelops has been marked as a joint operation among civil, mechanical, chemical, and aeronautical engineers; physicists; and many others. The barriers between classical hydrodynamics and empirical hydraulics have been torn down. Research, pure and applied, has been correlated and integrated with physical and mathematical analyses to yield a fundamental knowledge of the behavior of all fluids, liquid and gaseous alike.

Incidentally, hydraulic engineering, as such, must be distinguished from the basic science of hydraulics just as thermodynamics must be distinguished from mechanical engineering. In the traditional sense, hydraulic engineering is that branch of civil engineering which includes flood control, irrigation, drainage, river navigation and harbor control, water supply and distribution, and hydroelectric power. Not to be excluded, however, are certain aspects of soil conservation, oil and gas pipe lines, pumps and turbines, the fluid transmissions in new automobiles, and even the plumbing in homes! Today, men trained in each one of the major branches of engineering are engaged in some aspect of hydraulic engineering.

To speak of hydraulics research in generalized terms is obviously as foolish as to speak vaguely of research in chemistry or physics. One of the most convincing demonstrations of this fact is afforded by a partial list of the subjects of papers presented at a recent gathering[2] of hydraulic engineers from all parts of the country and all branches of engineering. This list includes the following wartime and peacetime topics: model tests on portable breakwaters, caissons, and harbor facilities; hydrographic surveys by means of radar; gas-globe phenomena associated with underwater explosions; submarine periscope vibrations; underwater missile design; cavitation of hydraulic machines and immersed bodies; applications of advanced photographic techniques and electronics to fluids research; recent developments in meteorology; variable-pressure water tunnels for aerodynamic as well as hydrodynamic research; wind tunnels for poison gas and smoke diffusion studies; aerodynamic instability of structural elements of bridges and buildings; hydraulic power transmissions; river hydraulics; development of the Missouri River; air entrainment in steep chutes; and fire nozzle design. If such a list is not sufficiently indicative, reference to the proceedings of previous conferences would reveal research on fish ladders (with real fish), plumbing fixtures, navigation locks, sediment transportation, etc.

Surely, in view of the researches reported above, it is unnecessary to suggest that hydraulic engineering and hydraulics research can contribute to the development of the Southeast. Georgia Tech's responsibilities thus become clearly defined. As one of the technical schools of the South, Georgia Tech is logically called upon not only to provide the laboratories and the staff necessary to implement similar research, but also to provide the academic facilities needed to train the young men of this region to participate in this work. The Civil Engineering Department's new laboratory, expanded staff, and curriculum in hydraulics and hydraulic engineering is Georgia Tech's initial response to this challenge.

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Figure 1. Research on complex pipe-flow phenomena is greatly facilitated by use of transparent plastic pipe.

CURRENT RESEARCH

Georgia Tech's new laboratory is already serving in its dual capacity as an instructional and research facility. Over 30 young men each quarter are participating in an improved undergraduate laboratory course, which at present is limited to civil engineering students. Many more students, including those from the industrial and the electrical engineering departments who are enrolled in expanded courses in the elements of hydraulics, benefit from occasional visits to the laboratory to see various fluid phenomena demonstrated or a hydraulic machine in operation. A number of graduate students have undertaken advanced research problems in the laboratory, and their investigations have resulted in the refinement of several pieces of basic research equipment. Projects now under way include an investigation of friction losses in spiral-welded, flanged steel pipe. As an auxiliary investigation, static tubes for pressure measurements are being compared with wall piezometers, and losses due to the static tubes themselves have been determined. In another study, losses in 3-inch Lucite tubing are being investigated (Figure 1). Unique features of instrumentation in the latter study include a simple asymmetric Venturi tube, also constructed of Lucite (Figure 2).

Two cooperative research projects have already been undertaken by the laboratory. In the first, engineers of the Water Resources Branch, U. S. Geological Survey, developed flow rating curves for a special design of a portable V-notch weir. Several of these instruments were gravimetrically calibrated for various conditions of upstream channel configuration. In the second study—and this can be added to the unusual researches listed above—Georgia Tech has collaborated with engineers of the Georgia State Highway Department in investigating the flow of water over highway embankments. Prosaic rather than spectacular, this study is nevertheless of great importance. Initial tests convinced the engineers that adequate protection against erosion could not be provided at a reasonable cost, and this decision resulted in raising several miles of a projected highway to a level that would seldom, if ever, be exceeded by flood waters. The problem does not end here, however. Similar embankments at other locations are overtopped every year. Engineers charged with the responsibility of recording flood flows need more information regarding the hydraulics of overflow. Thus, the study has been extended to include a comprehensive investigation of discharge ca-

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Figure 2. Asymetric Venturi tube constructed of Lucite.

THE KEYING OF QUARTZ CRYSTAL OSCILLATORS

By WILLIAM A. EDSON*

Quartz crystals have been used for many years to give accurate control of the frequencies employed in radio broadcasting and other communication services. In most of these applications, the crystals vibrate without interruption, often for periods of months. However, the use of crystals in telegraphy, where the vibration must be started and stopped many times per minute, involves additional problems, some of which are discussed in the following paper, which is based on work done at the Georgia Tech Engineering Experiment Station on a project sponsored by the Frequency Control Branch of the U. S. Army Signal Corps.

Alternating currents of low frequency are conveniently produced by means of rotating machines, and, since the frequency produced by any particular machine is proportional to the speed at which it is driven, a constant frequency is produced if a constant shaft speed is maintained. Frequencies in the order of a million cycles per second, however, are much more readily produced by vacuum tube oscillators. In this case, the frequency is determined by the components or elements of the oscillator circuit and is principally controlled by the resonator, which usually consists of a coil or inductor and an associated condenser or capacitor.

The frequency of such resonators varies somewhat, depending upon temperature, humidity, and other conditions. Moreover, such resonators have considerable damping or decrement; i.e., if the resonator alone is set into vibration, it will rapidly come to rest because of energy losses which result from the vibration. Such resonators are able to exert only a partial control over the frequency of an oscillator; therefore, the actual operating frequency is likely to depend upon applied voltages, the condition of the vacuum tube, and numerous other factors in addition to the natural frequency of the resonator.

QUARTZ CRYSTAL RESONATORS

For many years, rectangular slabs cut from natural crystalline quartz have been used as resonators for controlling the frequency of oscillators. A natural crystal of quartz, as it came from the ground, is shown in Figure 1.

The excellent performance which is obtained from these quartz resonators is due to several remarkable properties of the material. Natural quartz, unlike melted or fused quartz, is piezoelectric; that is, it changes its mechanical dimensions by a small amount if it is subjected to an electric field. Conversely, it produces an electric effect if it is subjected to a mechanical force or displacement. Because of this property, a block of quartz will vibrate if an alternating electric

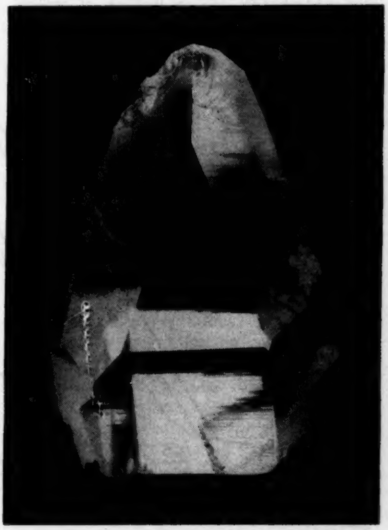

Figure 1. A natural quartz crystal.

*Professor of Electrical Engineering.

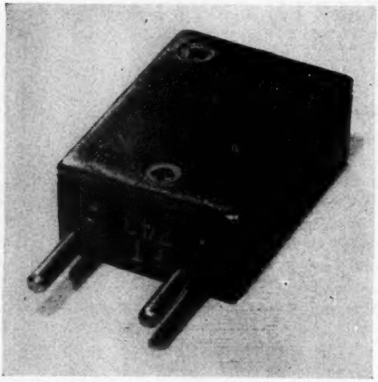

Figure 3. A commercial quartz crystal resonator.

voltage is applied between two metal plates on its opposite sides.

In addition, quartz has a very low value of damping or decrement, and a quartz resonator, therefore, is able to exert very complete control over the frequency of an oscillator. Moreover, the properties of quartz are nearly independent of temperature and humidity, so that the frequency of the resonator and hence of the oscillator is insensitive to temperature and other factors. Because the properties of quartz differ in different directions within the material, it is possible to cut resonator slabs in such a direction that the frequency is almost perfectly independent of temperature. In the so-called GT cut, for example, the frequency does not vary by as much as one part in one million over a temperature range of 200° F. Finally, quartz is a very stable and permanent material, so that frequency does not change with the passage of time.

The most common form of quartz resonator, sketched in Figure 2, consists of a relatively thin rectangular quartz plate, supported between two parallel sheets of metal which have approximately the same area. Figure 3 shows a commercial resonator which utilizes this construction.

PROPERTIES OF QUARTZ RESONATORS

The performance of a quartz resonator is best explained in terms of the equivalent electrical circuit. Evidently, this circuit must include a shunting condenser because the unit is essentially a parallel plate condenser with a quartz dielectric; this condenser is

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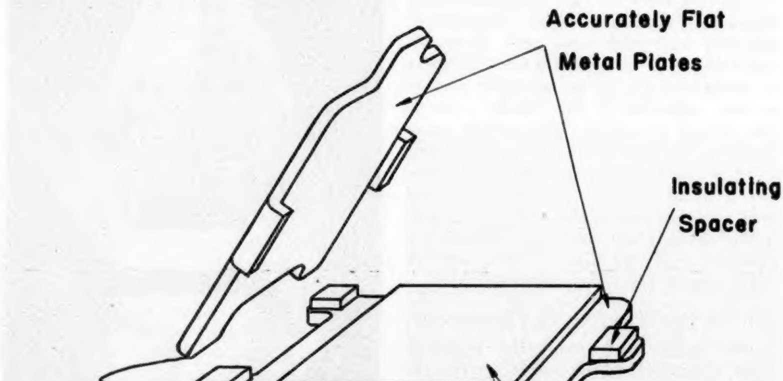

Figure 2. Method of assembly of quartz crystal resonator (simplified).

USE OF STRESSCOAT IN DESIGN AND STRESS ANALYSIS

By GEORGE K. WILLIAMS*

"Stresscoat," the trade name of a series of brittle lacquers and associated equipment produced and sold by the Magnaflux Corporation, has proved to be very useful in the design and development of machine parts and in the study of theoretical stress problems. These brittle lacquers crack at very low strain, at right angles to the direction of maximum principal stress. By loading a machine part which has been coated previously with Stresscoat, areas which are subject to high stress at the surface may be detected readily. The magnitude of stress at which these cracks first appear may also be determined. Since stress concentrations at the surface are the cause of early fatigue failures, much can be done to locate and evaluate such conditions by application of Stresscoat.

Stresscoat analysis is coming into wider and wider use as a rapid, efficient method of determining excess strain in machine and structural parts under load. This method has several advantages, discussed in detail below; these are: (1) the gage length measured is very small; (2) the survey of stresses is made over a whole area, rather than of a line or single point; (3) the method can be used on curved surfaces, in sharp fillets, and in places where other types of strain gages are not usable; (4) it reveals progressive development of high strain areas if loaded in increments; and (5) it is responsive to dynamic loading in the same manner as to static loading.

Each of the above advantages deserves more detailed attention. In regard to the first one, it may be noted that the effective gage length of the Stresscoat material is a function of the load and coating thickness, and varies from a very few times up to many times the thickness. This is evident from examination of the stress patterns, which show cracks spaced apart many times the thickness of the coating when the pattern begins to form. These cracks may be an eighth of an inch or more apart and are usually short in length. As the strain increases, the cracks increase in length and join with others, forming continuous cracks at right angles to the direction of maximum tensile stress. At the same time, intermediate cracks appear, between the initial ones. This process continues as the strain in the object being tested increases until the spacing between the cracks may be as low as two or three hundredths of an inch when the material is stressed nearly to the yield point.

The usual mechanical strain gage, however, has a gage length of an inch or more, although special gages measure strain over as little as a quarter of an inch. Since the strain indication from such an instrument is obviously the average strain over the gage length, it is immediately apparent that considerable variation in strain may exist in the gage length required for a mechanical extensometer which would not be indicated by such an instrument but would be by a Stresscoat pattern.

The electric strain gage has the same limitation, since it, also, gives an indication of the average strain over a comparatively large gage length. However, specialized electric strain gages have been developed with gage lengths of as small as a sixteenth of an inch in an effort to overcome this disadvantage.

The second and perhaps equally important advantage of Stresscoat, the survey of strain over an area rather than at a single point, is unique. All other common strain-measuring devices measure the strain only at the place where the gage is attached, either between gage points, in the mechanical type, or on a narrow strip in the electrical type. Unless the approximate location of maximum stress is known, it may be missed entirely with either mechanical or electrical gages. With Stresscoat, on the other hand, any area or portion of an area where the strain exceeds the strain sensitivity of the

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coating will be indicated by a pattern of cracks in the coating.

Stresscoat is particularly useful on surfaces with either single or double curvature, in internal corners, in fillets, and on machine or structural parts of irregular shape. Internal corners in machine parts are sources of high stress concentration and, in parts which are subject to repeated loadings, are the source of early fatigue failures. Mechanical strain gages cannot be used in such places, and with few exceptions, mathematical stress analysis is not applicable to these problems. Electric strain gages of small gage length have been used with some success. However, Stresscoat is admirably suited to such investigations. It can be readily applied to irregular surfaces; it locates the areas of high stress and, with proper technique, will give a close approximation of the stress concentrations existing under any load. It can be used on the machine part without damaging it, and, in some cases, tests may be made on a part installed in a machine under full operating loads. If this is not possible, the loads may be simulated in a laboratory test set-up.

By increasing the load in increments, Stresscoat will reveal the areas which have high strain and the approximate load at which the calibrated strain sensitivity of the coating is reached. It also has the big advantage of showing up highly stressed regions which had not been anticipated and which might not have otherwise been found. In this manner, faults which might have shown up only after the part was in service may be anticipated and corrected by design changes.

The response of Stresscoat to dynamic loading is apparently instantaneous, and calibration is reasonably close to that for static loading. This means that parts subject to rapidly varying loads can be tested under load with Stresscoat to determine the areas subject to excessive stresses. It has been used with success to study impact stresses in drop hammers and similar machines. Two notable applications which have been made are studies of stresses in large caliber military rifle barrels and in the breeches of shotguns. Both of these tests were made by actually firing shells with the usual explosive charges. Under such rapidly changing loads, the strain patterns opened under the impact load and closed immediately, but were brought out readily by a red dye-etchant. Other similar applications have been made to problems where the load varies very rapidly. The nature of the Stresscoat is such as to indicate peak stresses, which are the ones of greatest interest to the designer.

LIMITATIONS

It would not be fair to discuss the advantages of Stresscoat without discussing its limitations also. The important disadvantages are: (1) the coatings are sensitive to temperature and humidity variations; (2) the calibration is applicable only to the first cracks formed; (3) only limited accuracy of calibration is possible; and (4) the method requires spray-gun application and from 12 to 24 hours of drying time.

The sensitivity of Stresscoat to temperature and humidity variations is one of its biggest drawbacks. To remedy this failing, a variety of coatings together with a selection chart is supplied by the manufacturer, to be used for different humidity conditions. Strain calibration bars are also supplied, to be coated and dried at the same time as the test specimen. These should be kept in the immediate vicinity of the sample so that conditions are identical for the calibration bars and the specimen. Drying and testing should take place at nearly constant temperatures. Low room temperatures increase the sensitivity of the coating, and temperatures just above the freezing point of water cause crazing of the pattern, which renders it useless for obtaining strain patterns. However, special low temperature coatings have been developed which are usable down to 20° F.

Calibration of the strain patterns formed in Stresscoat lacquers are dependable at one strain only, the strain at which the first cracks appear. Qualitatively, however, the patterns show the strain conditions quite well. As discussed previously, the first cracks appear with quite a wide spacing, and tests indicate a close correlation between strains in test specimens and strains in calibration bars. As loads are increased, the cracks first extend lengthwise and then new cracks appear between the original ones. Further increases in load extend these cracks and cause new ones in the intervals between. This

process continues until the elastic limit is reached. Up to the strain corresponding to the elastic limit, it may be said that the strain is approximately inversely proportional to the spacing of the pattern cracks. Beyond the elastic limit, the cracks will still follow the same relationship with strain, but the strain is no longer proportional to the stress. At or shortly beyond the yield strength of the material, the Stresscoat begins to flake off.

Qualitatively, then, any area showing cracks has been stressed to a value exceeding the strain sensitivity of the coating as indicated by the calibration bar. Also, the closer the spacing of the cracks, the higher the stress, and areas where the Stresscoat has flaked off indicate areas where the stress has exceeded the yield strength of the material.

The accuracy of the calibration under laboratory conditions, where temperature and humidity do not fluctuate greatly, can be kept within plus or minus ten per cent with careful technique. With ordinary care, the accuracy may be depended upon to within plus or minus 15 per cent.

Stresscoat lacquers require spray-gun application to obtain a coating of uniform thickness satisfactory for calibration. While the thickness of the coating can vary considerably without affecting the calibration seriously, application with a brush will not give a coating that is uniform enough for good results. Some skill is required for good spray-gun application, but the technique is rapidly acquired and a beginner can achieve satisfactory results after a few tries. Since all of the necessary spraying and other miscellaneous equipment are supplied with the set of lacquers, this presents no serious obstacle to its use.

COMPRESSIVE STRAINS

Stresscoat brittle lacquers form patterns only when the coating is strained in tension. Offhand, therefore, it would seem that Stresscoat was useful for measuring tensile strains only. By modification of techniques, however, Stresscoat can be used to measure compressive strains also. Two methods are commonly used. The first consists of preloading the specimens and spraying and drying them in the preloaded condition. The calibration bars are sprayed and then loaded while drying. When the required drying time has elapsed, the loads on both specimens and calibrating bars are released at the same time and at about the same rate, and patterns will form. Since the areas subjected to the greatest compressive strains will elongate the most upon release of the load, the patterns will indicate the areas of highest compressive strain. Calibration with the test bars will give approximately the same accuracy as for tensile test specimens.

The second method utilizes the plasticity of the Stresscoat lacquer. If the coating is loaded in compression and the load is maintained for a period of time, plastic flow of the material will neutralize compressive stresses in the coating itself. If the compressive load is then removed quickly, the coating becomes loaded in tension, and patterns will form. As before, the patterns will occur where the compressive strains are highest and will extend to any area where the strain exceeds the strain sensitivity of the material. Calibration is much less accurate than with the first method described. However, this latter method serves well for qualitative analysis and in many cases is sufficient, since compressive stresses are not usually the source of trouble in either structural or machine parts.

LOCKED-IN STRESSES

Stresscoat is also very useful for showing locked-in stresses in machine components. Such stresses may have been caused by improper control of metallurgical processes during manufacture, misalignment during assembly, etc. Improperly heat-treated parts or castings with high internal stresses caused by uneven cooling and other similar factors can be examined with Stesscoat. The parts are sprayed and dried in the usual manner, then small holes are drilled in them, usually one-eighth inch in diameter or less and to a depth of several diameters. These holes tend to relieve any stresses in their immediate neighborhoods. If the area drilled is in compression, the Stresscoat will form concentric ring patterns about the drilled hole as a center. If the area is in tension, cracks in the pattern will extend radially outward from the center of the hole.

As an example of the above use, a manufacturer was having trouble with cracks developing in magnesium castings while in

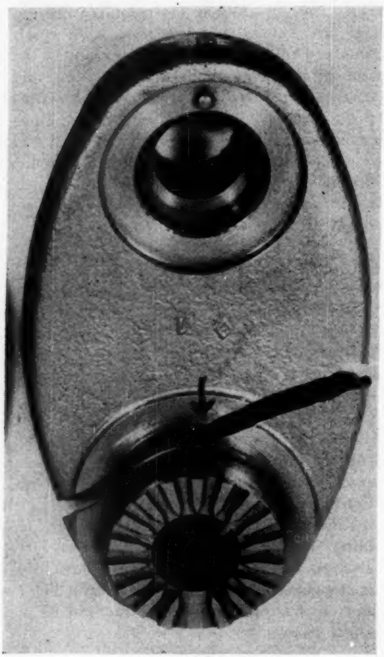

Figure 1. Service failure of crankshaft from excessive bending stress.

storage bins prior to machining or assembly. Analyzed with Stresscoat in the manner just described, the castings were found to have high residual internal stresses caused by poor foundry techniques.

Often, assembly of machine parts into the complete machine will induce internal strains. These may be caused by improper tolerances, misalignments, uneven tightening of bolts, etc. In many cases, such strains may be detected with Stresscoat by coating and drying the parts before assembly, following which the parts are assembled as rapidly as possible in order to obtain the pattern before plastic flow relieves stresses in the coating. This method has been used successfully on crankcases, gear housings, and similar parts.

SPECIFIC EXAMPLES

To illustrate the use of Stresscoat as an aid in improving design, reference may be made to photographs of a crankshaft, Figures 1-5. Figure 1 shows a typical service failure. Examination indicated that failure was caused by fatigue, starting in the fillet immediately beneath the crank pin. Bending stresses due to piston loads were believed to be the cause of the failure. Bending loads were then simulated by the static bending apparatus shown in Figure 2. These were applied in increments of 20 per cent, giving the high stress pattern at the fillets, with a maximum calibrated stress of about 90,000 pounds per square inch, as shown in Figure 3.

Several methods were tried in an effort to improve the design. The obvious one of increasing fillet radius showed an improvement of 50 per cent in strength when tested the same way. A carefully under-cut fillet, using great care to blend the under-cut with all adjacent surfaces, resulted in an additional 50 per cent increase in strength (Figure 4). This was not acceptable from a manufacturing standpoint, however, although the

Figure 2. Static bending stress being applied to crankshaft.

increase in strength was considered sufficient.

The modification finally decided upon was the one shown in Figure 5. By this method, paradoxically, the strength was increased by removing material. A hole drilled in the web weakened this area, forcing a redistribution of stresses around it. This, together with an increase in fillet radius, reduced the stress concentration at the fillet and gave a part which was acceptable from both strength and manufacturing standpoints.

USE AT GEORGIA TECH

Here at Georgia Tech, Stresscoat brittle lacquers have been used in research in the School of Aeronautics on thin shear webs of the type usually found in aircraft wing spars. Previous studies had developed acceptable theories for primary stresses in the web. The object of the Stresscoat studies

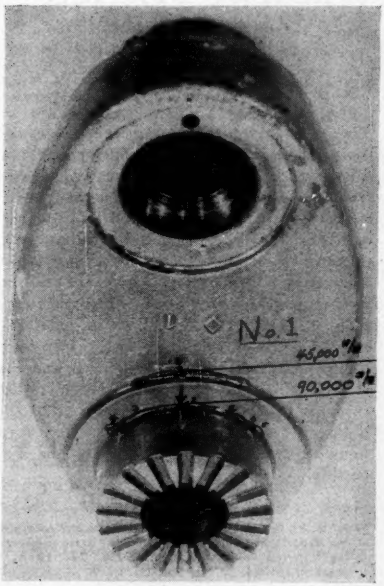

Figure 3. Bending stresses on original crankshaft design. Note concentration at center line of pin. Contours register spread of strain patterns with increasing increments of load each 20 per cent higher than previous one.

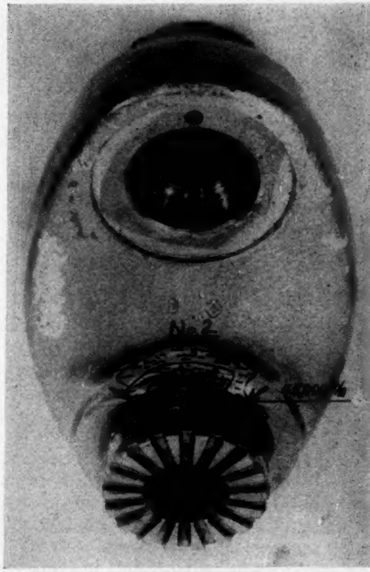

Figure 4. Redesign with expensive undercut fillet. An increase of 100 per cent in strength over the original design was obtained.

was to make preliminary analyses of secondary stresses in shear webs loaded beyond the critical buckling point. Solid shear webs and others with cut-outs were studied. Space limitations do not permit a discussion of the results here, but Figure 6 shows a typical pattern obtained during these studies.

A complete Stresscoat outfit with lacquers, dye-etchant, and other necessary supplies is available at Georgia Tech for use in research studies, both those of the School and those undertaken in cooperation with industry. It seems probable that this method of stress analysis will prove increasingly useful.

ACKNOWLEDGMENTS

Figures 1-5 are used through the courtesy of Jack and Heintz Inc., Cleveland, Ohio, and the Magnaflux Corporation, Chicago, Illinois.

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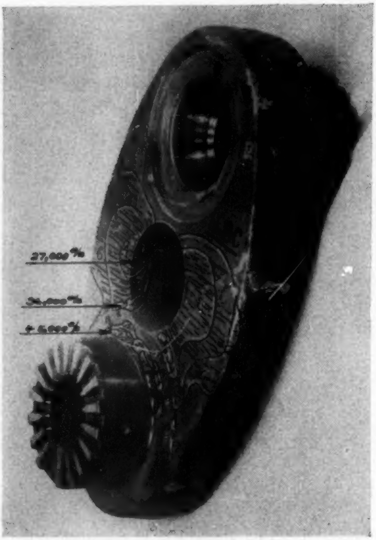

Figure 5. Redesign with hole in center of web and increased radius of fillet. An increase of 100 per cent in strength over the original design was obtained. Note broad distribution of stress around center line of pin.

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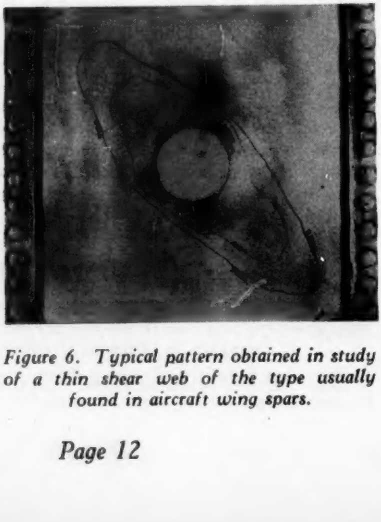

Figure 6. Typical pattern obtained in study of a thin shear web of the type usually found in aircraft wing spars.

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RECENT STATION PUBLICATIONS

BULLETIN

Hosmer, Joseph B., *Economic Aspects of the Naval Stores Industry*. State Engineering Experiment Station Bulletin No. 12, 1948. 75 cents.

The price, production, and demand gyrations of the naval stores industry and the shifts which have brought about its concentration in South Georgia and North Florida constitute an intriguing chapter in Georgia's economic history. This bulletin has been prepared in response to the need for a summarization of the problems involved and the facts from which they arise. The basic viewpoint chosen has been that of the relationship of naval stores (rosin and turpentine) to the economic pattern of the area and the industrial development of Georgia, rather than the more usual and narrow one of the industry alone. Some 27 tables and four figures provide documentation for the discussion.

REPRINTS

Weil, B. H. and Lane, J. C., *Reproduction Techniques for Reports and Information Service*. State Engineering Experiment Station Reprint No. 22, 1948, 8 pages. 25 cents.

Technical reports and the searches, surveys, abstract bulletins, etc., of information services must be properly reproduced if their contents are to serve with maximum effectiveness. The prime criterion in this connec-

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THE INDUSTRIAL APPLICATIONS OF PATENTS

By HARRY H. SEMMES* *and* B. H. WEIL**

This is the last article of a RESEARCH ENGINEER *series intended to review for engineers and industrialists the salient aspects of patent protection, a subject of considerable importance in this industrial age. In order to make this information more readily available, the entire series has been reissued in booklet form.*

Over half a century ago, a Commissioner of Patents resigned from the Patent Office because he felt that the field of invention had by then been completely exhausted. In this "atomic age," it would take a man of limited vision, indeed, who would again be tempted to make such a remark in anything but jest.

While patents have been assailed by radicals as the "tools of capitalists and monopolists," and praised by others as the incentives to industrial progress, it is not timely here to consider the "morals" of the system, but rather to complete the outline of working practices begun in the earlier articles of this series. Assuming, then, that an "invention" has been made, what can the inventor do with it before, during, and after patenting?

BEFORE PATENTING

Very little in the way of use can safely be made of an unpatented "invention" before an application for a patent has been filed. Even if records have been carefully kept and authenticated, the inventor is required by law to show "reasonable diligence" in applying for a patent after completion of his invention, and the invention itself cannot be "in public use or on sale in this country for more than one year prior to his application" if a valid patent is to be obtained. An attempt may be made to practice the invention secretly, of course, but difficulties arise if it is deemed advisable to seek patent protection on it at a later date.

The questions are often asked: "What if I can't afford to get a patent?" "Is it safe to disclose my unpatented invention to some company in the field and to ask them to patent it for me if they are interested in buying it from me?"

These questions are answered rather well in the words of a recent publication: "An inventor may sell his tentative rights in an invention at any time, but it is generally believed safer to wait until the patent application has been filed in order to establish a filing date. Most businessmen are reluctant to examine inventions prior to the filing of an application by the inventor."[1]

This reluctance is based upon several valid reasons. First of all, the "invention" may duplicate one being legitimately developed by the manufacturer in question, thus bringing up the possibility that he may be signing away his own rights if he agrees to examine an invention submitted to him "in confidence," or perhaps letting himself in for unwanted litigation. Secondly, the industrialist has no positive assurance that any "unpatented invention" will eventualy be given protection by a patent grant, and at most "the purchase agreement is usually made on a tentative basis pending the outcome of the Patent Office (final) action on the application."[1]

As mentioned in the first article in the series, the inventor must take proper precautions against disclosure of his invention to anyone other than his attorney and witnesses, prior to the filing of his application, since any unscrupulous person could file an application based on an incautious disclosure. Even when it appears safe to disclose the details of an invention to an interested party, the inventor "should not reveal the date of conception, reduction to practice, or any of the important dates in the chronological record,"[1] nor should he reveal the serial number and filing date of his patent application after one has been made. These precautions will prevent the informed faking of records by dishonest parties.

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DURING PATENTING

Once an application has been filed, an inventor "is fairly safe in revealing his invention to trusted firms and individuals."[1] Whether or not he can sell his invention, however, still usually depends on his actually obtaining a patent which can be analyzed for commercial worth; this can occasionally be done after the first few patent actions have indicated that a patent will actually be issued with at least part of its claimed breadth.

AFTER PATENTING

The owner of an issued patent may exploit his patent grant in several ways. If it is a "basic patent" or if its use does not infringe on unexpired patents, he may finance and develop his invention himself; obtain financial aid from others in this venture, in return for various rights; assign or license the patent to an interested industrial organization or individual (either by outright sale or on royalty basis); etc. The latter steps may also be followed even when unexpired dominating patents exist in the field, and a license or cross-license may be negotiated which will enable the patent owner to use his patent in combination with those which would otherwise legally prohibit its actual use.

Space limitations do not permit more than bare mention here of the legal technicalities involved in patent assignments and licenses. "Since an assignment is a contract and its terms are binding, an inventor, to protect his interests, should have it prepared by an attorney in whom he has full confidence."[1] Details of such contracts—exact rights, length of license, amount of royalties, methods of accounting and payment, etc—must be carefully considered, since, as regards the "business" of patents, assignments and licensing are matters with which individual inventors are ordinarily most concerned. Incidentally, patent assignments, to take legal effect, must be recorded in the U. S. Patent Office; this may be done upon application for the patent, while it is pending, or at any time during the life of the patent.

Obviously, the decisions involved in the industrial applications of patents are by no means simple. The commercial merit of a patent is dependent upon its validity—its novelty, utility, and degree of invention, plus the proper adherence to restrictions on public disclosure and diligence in completing the invention and applying for a patent. Moreover, the value of the patent is determined, to no small degree, by the skill exhibited in its drafting and prosecution. In the ultimate, of course, the actual "strength" of a patent can never be determined without adjudication, but a really good patent is seldom involved in litigation. It is true that, in recent years, most of the patent suits which have been referred to the Supreme Court have resulted in invalidation or limitation of the patents involved, but it may be pointed out that these patents represented only a minute fraction of those issued, and that litigation usually occurred because the defendant believed that the patent or patents involved were invalid, or not infringed, and so conducted his business.

PATENT INFRINGEMENT

Any consideration of the details of patent litigation—infringement suits—is beyond the scope of this series. It might be pointed out, however, that "ignorance is not bliss" in the case of patent infringement; "it is not necessary, in order to constitute an actionable tort, that the infringer *know* that the article or thing which he makes, uses, or sells infringes a patent."[2]

The purchaser of a patented machine has the right to use it until it is worn out, and therefore may repair it and substitute new parts for worn ones. He may build such parts or purchase them where he pleases without obligation to pay royalty and without infringement, so long as the parts in question are not covered by separate patents and do not constitute the patentable feature. Parts requiring frequent replacement, moreover, may be renewed so long as there is no patent covering them as part of a general combination; typewriter ribbons and flashlight bulbs are examples of this.

"If a man buys a patented machine already assembled, it is not infringement for him to take it apart for overhaul, repair, and reassembly; also, he may sell it either assembled or demounted. If another man buys the parts of a disassembled patented

machine, however, it would be infringement for him to assemble the parts without the patent owner's permission, and, likewise, to use or sell the machine after he had assembled it."[3]

Production of a patented article (or use of a patented process) for experimental purposes is not "actionable infringement" unless combined with commercial use or sale. Moreover, the intent to use a patentable invention is not grounds for litigation; use must be *actual* for actionable infringement, and "mere possession not followed by actual use"[2] is not infringement. "In general, a 'process patent' is not infringed by one who merely uses or purchases the *product*."[2]

"A device or machine, in order to infringe a patent, must perform substantially the same function or accomplish substantially the same result as the patented invention; furthermore, it must perform such function or accomplish such result by substantially identical means, and the principle or mode of operation must be substantially the same. Unless form is of the essence of the invention or is a distinguishing characteristic thereof, or unless form and substance cannot be separated, *mere differences* in form are immaterial.

"Infringement is not avoided merely because one of the parts of the infringing machine which performs the same function as that of the patented invention also performs an additional function; neither will the addition of one or more elements, parts, or features to a machine which constitutes, in substance, the patented invention, avoid infringement. Infringement is not, in general, avoided by joining or consolidating two or more parts, elements, or features into one integral part; or by a mere rearrangement of parts where there is no change in function, or substantial change in operation; or by substituting equivalent elements for those set forth in the patent claim."[2]

When the owner of a patent deems that his patent has been infringed and has complied with the requirement (in the case of an article of manufacture or product) that his product "where practicable" has been marked "patented," together with the date and number of his patent, he may turn to the courts for redress, provided that he has first notified the infringer of his infringement and such has continued; "however, it is not necessary that he warn infringers if he seeks other relief, such as an injunction."[2] All such actions are within the jurisdiction of the Federal Courts, although matters of contracts, licenses, etc., may be dealt with by state courts.

Jurisdiction in infringement suits lies with the court of the particular Federal District where the defendant resides or where the infringement was committed as part of a regular enterprise. "The Court of Claims also has jurisdiction in the case of claims against the U. S. Government."[2] From these courts, appeal may be made to the U. S. Circuit Court of Appeals. In certain cases, the United States Supreme Court will review these decisions, by issuing a writ of certiorari to the lower court to send up the record for review. "No damages or profits can be recovered for any act of infringement occurring more than six years before the suit is begun."[2] Details of such litigation are not pertinent here.

MISUSE OF PATENTS

Because of the nature of the patent grant, which gives a limited and generally beneficial monopoly in turn for full disclosure of the invention (so that the public may use it freely after the expiration of the patent), the application of patent rights is sometimes subject to abuse. Some few of the prohibitions against unlawful use ought therefore to be considered here.

For one thing, patents cannot be used as a cloak for a system of interlocking contracts designed to monopolize an industry. The case of the United States v. Masonite Corporation, reported in 316 U. S. 265, 86 L. Ed. 1461, was decided by the Supreme Court in 1941, the opinion being written by Mr. Justice Douglas. This case is important as overturning the former decision concerning the use of "del credere"* contracts, involving the General Electric Company. In this former case, the General Electric Company employed "del credere" ar-

*According to Webster's International Dictionary, "del credere" is defined in mercantile law as "designating the obligation of an agent or factor who warrants or guarantees to his principal the due payment or performance by those with whom he deals on credit as such agent or factor, his commission, which is higher than in other cases, being called a *del credere commission*. The *del credere* agent becomes liable upon the failure of the debtor to pay. The agent's undertaking is not a guarantee required to be in writing by Sec. 4 of the Statute of Frauds."

rangements to enable them to fix the price in the hands of the distributors (U. S. v. General Electric, 272 U. S. 476, 7 L. Ed. 362), and this was held a legal arrangement by the United States Supreme Court. In this instant case, Masonite, which had controlling patents and which relied upon the earlier General Electric case, attempted to distribute its material through agents who did not take title but were merely "del credere" agents. It was evident that there was collusion between the parties to the "del credere" agency contracts, since each of the parties at some time or other was informed of the price, the fact that other people were selling at the same price, and the fact that other people had the same contracts.

On page 1474 of its decision, the Supreme Court said:

"Since there was price-fixing, the fact that there were business reasons which made the arrangements desirable to the appellees, the fact that the effect of the combination may have been to increase the distribution of hard-board without increase of price to the consumer or even to promote competition between dealers, or the fact that from other points of view, the arrangements might be deemed to have desirable consequences would be no more a legal justification for price-fixing than were the 'competitive evils' in the Socony-Vacuum Oil Co. Case."

Page 1475:

"Certainly if the del credere agency device were given broad approval, whole industries could be knit together so as to regulate prices and suppress competition."

Page 1476:

"And when it is clear, as it is in this case, that the marketing systems utilized by means of the del credere agency agreements are those of competitors of the patentee and that the purpose is to fix prices at which the competitors may market the product, the device is without more an enlargement of the limited patent privilege and a violation of the Sherman Act. In such a case the patentee exhausts his limited privilege when he disposes of the product to the del credere agent."

Page 1478:

"And if there were any lingering doubt as to whether the appellees were parties to a conspiracy it is dispelled at this point. A committee of the appellees was appointed to draft the new agreement. The agreement was completed after meetings at which representatives of all of the appellees attended. The 1941 agreements were the product of joint and concerted action."

The Supreme Court of the United States has in many cases held that the patent grant cannot be extended to cover the monopolization of an unpatented product, which product lies outside the protection of the patent.

For example, a patent on a container for a freezing agent such as solid carbon dioxide freezing agent such as solid carbon dioxide cannot be used to force a purchaser to buy the solid carbon dioxide from the patent owner, since the frozen carbon dioxide is an unpatented material purchasable on the open market (Carbice Corporation of America v. American Patents Development Corporation, *et al.*, 8 U. S. P. Q. 211, 283 U. S. 27, 75 L. Ed. 819). Again, in Morton Salt Company v. G. S. Suppiger Co., 319 U. S. 488, 86 L. Ed. 363, the patent owner was prevented from suing for infringement because the patent was used to restrain competition in unpatented supplies.

In this case, the patent owner was making and leasing patented machines for making salt tablets. Commercial canners were licensed to use the patented machines conditionally with the agreement by them that only unpatented salt tablets made by the patent owner's subsidiary were to be used with the leased machine. The Court said:

"Undoubtedly 'equity does not demand that its suitors shall have led blameless lives,' Loughran v. Loughran 292 U. S. 216, 229, 78 L. Ed. 1219, 1226, 54 S. Ct. 684; cf. Keystone Driller Co. v. General Excavator Co., 290 U. S. 240, 241-245, 78 L. Ed. 293, 295-297, 54 S. Ct. 146, but additional considerations must be taken into account where maintenance of the suit concerns the public interest as well as the private interests of suitors. Where the patent is used as a means of restraining competition with the patentee's sale of an unpatented product, the successful prosecution of an infringement suit even against one who is not a competitor in such sale is a powerful aid to the maintenance of the attempted monopoly of the unpatented article, and is thus a contributing factor in thwarting the public policy underlying the grant of the patent. Maintenance and enlargement of the attempted monopoly of the unpatented article are dependent to some extent upon persuading the public of the validity of the patent, which the infringement suit is intended to establish. Equity may rightly withhold its assistance from such a use of the patent by declining to entertain a suit for infringement, and should do so at least until it is made to appear that the improper practice has been abandoned and that the consequences of the misuse of the patent have been dissipated. Cf. B. B. Chemical Co. v. Ellis, decided this day (314, U. S. 495, post, 367, 62 S. Ct. 406)."

It is clear that the Supreme Court of the United States will not tolerate any device based on patents to extend the lawful patent monopoly beyond the confines of the legal grant.

However, license contracts involving patents are a legal and customary method of doing business. It is only when the con-

tracting parties go beyond the scope of the legal monopoly of the patent grant that the Courts will not enforce the contract. In a recent case, the United States Supreme Court has upheld a license contract where the licensee was required to assign his improvements to the licensor (Transparent Wrap Machine Corporation v. Stokes & Smith Company; Advance Sheets Law Edition Supreme Court Reports, Oct. Term 1946-1947, Volume 91, No. 7, Page 451, decided February 3, 1947).

OTHER CONSIDERATIONS

This series of articles on patent technology cannot pretend to have even touched upon all of the important aspects of this subject, on which entire libraries have been collected. If nothing else may be derived from the facts presented, it will have achieved its purpose if it has served to stress the need for the employment of properly accredited patent attorneys or agents, or at least the further study of the subject by those who prefer to handle their own work.

Incidentally, this series has not attempted to delve into the intricacies sometimes involved in determining who is the inventor, or who are the inventors, of a given invention. It should be pointed out, however, that a patent, to be valid, must be issued only to the inventor or inventors who actually made the invention. For example, assignment of a task does not constitute invention on the part of the supervisor unless he gives complete instructions as to how the work is to be conducted, in which case the mechanics or operators are not even co-inventors unless they make some contribution "out of the line of duty."

It might also be noted that the basic patent law includes provision for protection of new, original, and ornamental designs for articles of manufacture. "Although the procedure for obtaining design patents is somewhat simpler, they are obtained substantially like mechanical patents,"[1] with the grant running for 3.5, 7, or 14 years, depending on the request of the inventor and payment of the corresponding fee. Something more than "ordinary skill in arrangement" of common features is required for the grant of a design patent.

The United States patent system has been the subject of many attacks, a large number of which have centered around attempts to force the compulsory licensing of patents, either by act of Congress or by judicial fiat. Numerous reforms have been urged, and many have been made.

Whether or not our patent system is "perfect," only the deliberately obtuse will deny that it has been of inestimable value to industry and to the individual patentee. Under the security of the patent grant, free enterprise has produced in this country an economy that has made us leaders of the world in standards of living. So long as this nation continues its present ways, patents will continue to aid in its development and to be of importance to its industries and citizens.

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2. McCullough, C. B. and McCullough, J. R., *The Engineer at Law*, Volume II, The Collegiate Press, Inc., Ames, Iowa, 1946.
3. Unpublished paper by W. H. Deitch, Gulf Oil Corporation.

QUARTZ CRYSTAL OSCILLATORS

Continued from Page 6

shown as C_h in Figure 4. The resonant behavior of the quartz plate is accounted for by the elements L_0 and C_0. At frequencies near the resonance of the quartz block, the effect of these elements is much larger than that of C_h. Finally, if the damping, which is small, needs to be taken into account, the resistance R_0 must be introduced.

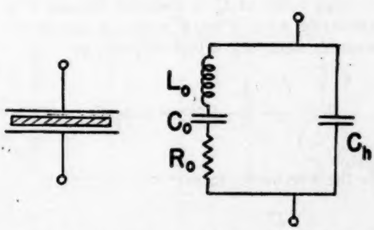

Figure 4. Electrical circuit equivalent to a quartz crystal resonator.

The usefulness of a quartz resonator may be measured in a number of ways. For the present purposes, however, only a few parameters need be mentioned.

The resonant frequency is the frequency at which the plate vibrates with the terminals short-circuited. In terms of the equivalent circuit, this frequency is

$$f_o = \frac{1}{2\pi\sqrt{L_oC_o}} \text{ (cycles per second)}. \quad (1)$$

The anti-resonant frequency is the frequency at which the plate vibrates with the terminals open-circuited. In terms of the equivalent circuit, this frequency is

$$f_n = \frac{1}{2\pi\sqrt{L_oC_n}} \text{ (cycles per second)}, \quad (2)$$

where C_n, the capacitance equivalent to C_o and C_h in series is

$$C_n = \frac{C_oC_n}{C_o + C_h}. \quad (3)$$

The capacitance ratio, which has an important effect upon the usefulness of a resonator, is given by

$$n = \frac{C_h}{C_o}. \quad (4)$$

The selectivity or quality factor of the resonator is given by

$$Q = \frac{2\pi f_o L_o}{R_o} = \sqrt{\frac{L_o}{C_oR_o^2}} \quad (5)$$

A large value of Q is desirable because it is associated with a small value of the decrement or damping, which is given by

$$\Delta = \frac{27.3\, f_o}{Q} \text{ (db per second)}, \quad (6)$$

or the alternative form

$$\delta = \frac{27.3}{Q} \text{ (db per cycle)}. \quad (7)$$

For a fairly typical crystal, these constants are:

$R_o = 30$ ohms
$L_o = 1/16$ henry
$C_o = 0.04$ mmf
$C_h = 28$ mmf
$n = 700$
$f_o = 3.18$ megacycles
$Q = 12{,}500$
$\Delta = 6960$ db/sec
$\delta = 0.00218$ db/cycle

The last figure may be taken to show that the resonator alone, if set vibrating, would execute 2750 complete vibrations before the amplitude fell to half its original value.

CRYSTAL OSCILLATOR CIRCUITS

A number of circuits have been devised for obtaining electrical oscillations of stable frequency from a quartz crystal and a vacuum tube; one familiar form is shown in Figure 5. This circuit has several excellent features. It does not oscillate if the crystal is removed or damaged, so that there is no risk of operation at some undesired frequency. It operates satisfactorily even with crystals which are mediocre in their electrical response. In addition, it will operate at frequencies ranging from a few hundred kilocycles to a few megacycles without any change except replacement of the crystal. This is of great practical importance, particularly in military equipment where simplicity is essential.

A second widely used circuit is shown in Figure 6. This circuit has the advantage that one terminal of the crystal is at ground potential. Its disadvantages are that it requires a coil in the plate circuit of the tube and that any single coil is suitable for operation with crystals only over a narrow range of frequencies.

KEYING THE CRYSTAL OSCILLATOR

Crystal oscillator circuits are ordinarily designed so as to reduce to a minimum the variations of frequency which result from changes of temperature, voltage, tube parameters, and the values of the circuit constants. In general, this consideration leads to a light loading of the crystal. That is, the circuit constants are so chosen that the damping or decrement of the total circuit is

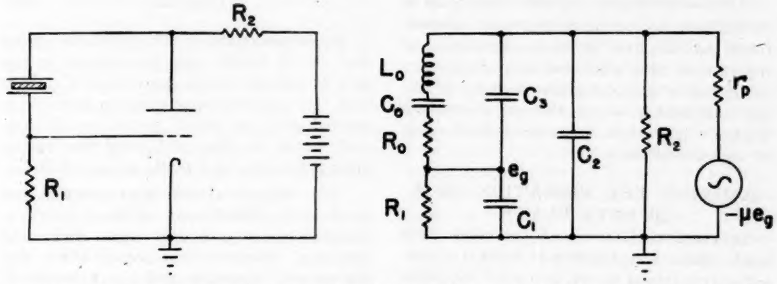

Figure 5. The Pierce crystal-controlled oscillator circuit. At left is a diagram of actual circuit connections, while at right is the equivalent circuit, including tube and crystal capacitances.

only a little larger than that of the resonator itself.

In such a circuit, oscillations die out rather slowly when the power is turned off and build up slowly when the power is applied. Accordingly, such a circuit is not well adapted to keying for high-speed telegraphy because the individual characters do not remain separate.

It therefore appears that a fundamental conflict exists between the requirements for high-speed keying and for frequency stability. Fortunately, however, this conflict is not incapable of compromise, and there are several ways in which acceptable results may be obtained.

BASIC METHODS OF APPROACH

The most obvious way of improving the keying speed of a crystal-controlled oscillator is to degrade the Q or increase the decrement of the system. This can be done by adding resistance to the circuit or by coupling the crystal more tightly to the oscillatory circuit. This is not an ideal solution, but it is the most practical approach in most cases, and an improvement of some ten times in the allowable keying speed of ordinary oscillators may be made without seriously affecting the frequency stability.

It should be noted that the problem of keying an oscillator really comprises two separate problems. If oscillations build up too slowly when the key is closed, the characters will not be properly formed. If oscillations die out too slowly when the key is opened, the space between characters will be filled in, and the signal will be difficult or impossible to read. Experiments show that the wave form of Figure 7 represents approximately the worst usable signal.

The rate at which oscillations die out is controlled principally by the resistances which are associated with the crystal in the circuit. Adequately rapid rates of decay can be secured by the use of low resistances, but this procedure aggravates the problem of securing rapid rates of oscillation build-up.

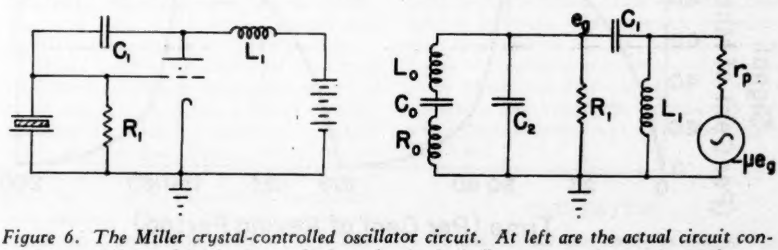

Figure 6. The Miller crystal-controlled oscillator circuit. At left are the actual circuit connections, while at right is the equivalent circuit, including tube and crystal capacitances.

One would expect the rate of build-up of oscillations to be approximately proportional to the gain or transconductance of the vacuum tube used, and, in ordinary circuits, this is approximately correct. In exceptional cases, however, the rate of build-up reaches a maximum for some definite value of transconductance.

DAMPING THE VIBRATION OF A QUARTZ PLATE

In keyed oscillators and for some other applications, it is desirable to bring a vibrating quartz crystal to rest in a relatively short time. For a variety of reasons, it is not practical to do this by means of mechanical friction. Accordingly, the results which can be secured by connecting an electrical network to the terminals of the crystal have been studied.

A consideration of Figure 4 shows that the crystal will vibrate with little damping if the terminals are either open-circuited or short-circuited. Moreover, the damping and the frequency observed in the two cases are approximately equal. If, however, a resistor is connected to the terminals of the crystal, an electric current will flow in this resistor as a result of the piezoelectric action, and the vibrations will be damped.

It is not difficult to show that the greatest damping which can be achieved in this way occurs when the external resistor is equal to the reactance of C_h at the resonant frequency of the crystal. Subject to this condition, the selectivity of the system is given by the simple formula:

$$Q = 2n. \qquad (8)$$

An investigation of the equations shows that the Q which may be achieved in this way is limited by the presence of C_h. It is clear that an inductance either in series or in parallel with the added resistor would partially cancel the effect of C_h and thus permit greater damping and lower values of Q.

The analysis of this more complex case is relatively difficult and requires careful interpretation of a fourth order differential equation. However, the results show that the greatest damping and hence lowest Q results when the reactance of the external coil is very close to that of C_h. With this condition and with a suitable value of resistor, the resulting selectivity is

$$Q = \sqrt{n}. \qquad (9)$$

For the typical crystal cited, this leads to a Q of approximately 26. The external resistor is best expressed by the condition that the Q of the external coil including this resistance shall be

$$Q_d = \sqrt{n/2}. \qquad (10)$$

In spite of the rapid damping which is achieved in this way, the frequency is not appreciably affected by the addition of the damping elements.

A PRACTICAL CIRCUIT

The most practical crystal-controlled oscillator circuit for most keyed applications is the Pierce circuit, shown in Figure 5. It

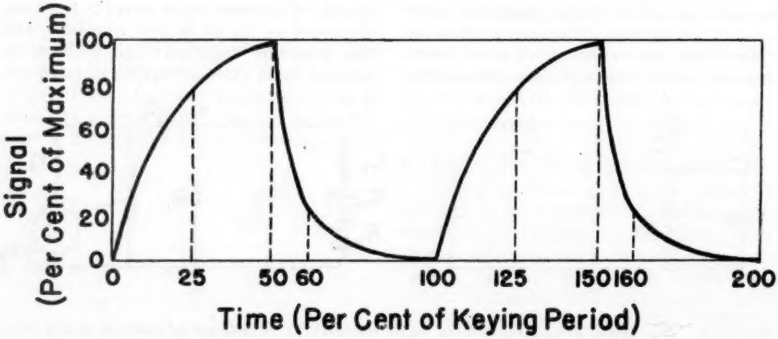

Figure 7. Wave form corresponding to a barely readable series of telegraphic dots.

differs from conventional circuits only in the relative values of the parameters, which are adjusted to produce rapid rates of build-up and decay of oscillation.

Rapid decay of oscillation is obtained by using a plate load resistor which is much smaller than usual. The grid-to-cathode capacitance is then artificially increased so that the load resistor is effectively in parallel with the terminals of the crystal.

Rapid build-up of oscillation is obtained by using a tube which has a large amount of gain. The transconductance used is considerably in excess of the minimum value which will produce stable continuous oscillations, and, because of the low resistor employed in the circuit, a reasonably high-gain tube is required to produce oscillations of any sort.

Figure 8 shows a circuit which operates satisfactorily without readjustment with crystals in the range of 2 to 10 megacycles. The keying wave form obtained in all cases was superior to that of Figure 7 at a keying speed of 45 dots per second. This is adequate to transmit teletype signals, and is more than adequate to accommodate the signals produced by the most expert hand keying.

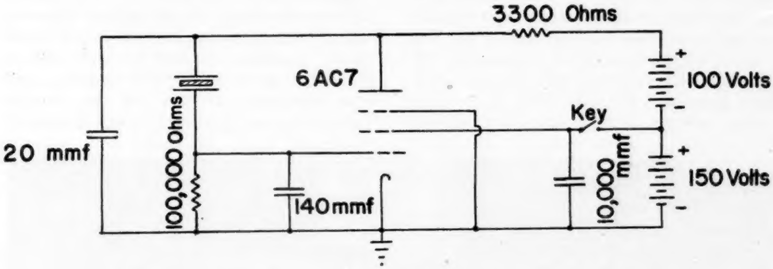

Figure 8. The Pierce crystal oscillator arranged for keying.

HYDRAULICS RESEARCH AND THE SOUTHEAST

Continued from Page 4

pacity, velocity distribution, and submergence effects. Tests so far have been conducted an a 1/6-scale sectional model of an embankment, located in a 3 x 3 foot glass-walled flume, as pictured on the cover of this issue. Plans are under way to investigate scale effect on a similar smaller-scale model, to be located in a 15-inch flume.

Model studies of hydraulic structures comprise a particularly spectacular variety of hydraulics research. Georgia Tech's Hydraulics Laboratory is too small to undertake many kinds of open-channel model studies, but the field is so broad as to include many types for which its facilities are particularly well-adapted. Figure 3 shows a hydraulic model which was tested at the U. S. Waterways Experiment Station, Vicksburg, Mississippi, as a step in the design of Allatoona Dam, now under construction near Cartersville, Georgia. Similar models have been constructed and investigated for most of the hundreds of major water-control structures built in recent years. That engineers have faith in hydraulic models research is perhaps best demonstrated by the decision of the Corps of Engineers to build a model of the entire Mississippi River, including all of its tributaries and reservoirs—a project which will occupy a ground area of approximately 220 acres.

CAVITATION

Cavitation, an occurrence accompanying extreme pressure reductions within flowing

liquids, occupies an important place on all lists of current hydraulics research. The engineering aspects of cavitation are largely concerned with the collapse of the vapor cavity, since, in the region of collapse, great damage may be done to adjacent boundaries. In recent years, cavitation research has been extended to include aerodynamic models, not because cavitation can occur in compressible fluids, but because the occurrence of cavitation is an indication of separation and inadequate "streamlining." Two principal types of cavitation testing apparatus are in general use today. The first involves the measurement of pressure distribution over the boundary in question without actually producing cavitation. The second involves a variable-pressure enclosed recirculating system, in which similarity of cavitation conditions is attained when the value of the "cavitation number" is made equal in model and prototype. In the first type, conditions conducive to cavitation are implied when measured pressure differentials, referred to a point in the undisturbed flow and interpreted in terms of prototype values, would indicate local pressures at any point in the system at or below vapor pressure. In the second type, cavitation is actually reproduced and evidenced both by the appearance of "white water" in the vicinity of the affected region and by its effect on pressure distribution over the affected boundary. First recognized nearly 50 years ago as a possible cause of pitting on marine propellers, cavitation now occupies the attention of all who are engaged in the design of pumps and turbines, high-velocity conduits, high-head regulating valves, structures exposed to high-velocity jets, high-speed underwater missiles, and even high-speed aircraft. In the Georgia Tech laboratory, the construction of a small,

Figure 3. Problems of design on Georgia's Allatoona Dam, under construction near Cartersville, were solved with this one-fiftieth scale model in the U. S. Engineer's laboratory at Vicksburg, Mississippi. Courtesy of U. S. Waterways Experiment Station.

low-velocity variable-pressure recirculating system for cavitation and allied research has just been completed. This new apparatus is intended primarily as an exploratory or pilot model, and will eventually be devoted to instructional use. Nevertheless, one of its first applications will be the investigation of certain aspects of aerial bomb flight characteristics.

GEORGIA RESOURCES

The largest demand for hydraulic engineering endeavor is still identified with the development and conservation of the nation's natural water resources, and it seems highly pertinent to focus attention on this subject as one which is of particular interest in this region. Few of Georgia's citizens realize how critically the future development of their state depends on the planned conservation and utilization of its undeveloped water resources. The state's five major rivers, the Coosa, the Flint, the Chattahoochee, the Altamaha, and the Savannah, together with their tributaries comprise both a vast natural resource and a highly complex problem, the planned solution for which is the responsibility of every citizen, public official, and public institution.

Georgia is fortunate in having so much of her hydroelectric resources already well-developed. In the mountains of the northeastern part of the state, on the Chattahoochee, Flint, and other rivers, many large dams and powerhouses are already in operation. Many additional sites remain, however, and these are capable of development when needed.

The hydraulic engineer's part in the useful development of water resources is not confined to water power alone, however. Power is but one objective of a river development program which should include the conservation and regulation of critically needed domestic water supplies, control of floods, promotion of river navigation, creation of new recreational resources and wild life refuges, abatement of stream pollution, conservation of artesian water supplies, and prevention of salt water intrusion in coastal areas. Each of these benefits must be sought if new industry is to be attracted to the state and if the health and prosperity of its future citizens are to be assured.

As has been demonstrated, hydraulics research is a diverse field of activity, and no single laboratory can reasonably expect to engage in work on all of its many aspects. As a stimulus to faculty and students alike, extracurricular research is a desirable ingredient of any laboratory program; however, if the same laboratory is intended to serve as an instructional device as well as a research center, a carefully formulated policy regarding research is of vital concern.

As an element of the Civil Engineering Department, the hydraulics laboratory at Georgia Tech might be expected to emphasize traditional civil engineering applications of hydraulics, since Georgia Tech has other laboratories fully capable of handling problems more closely associated with aerodynamics or thermodynamics. As regards "pure" research versus "applied" research, here, also, it is necessary that a balance of emphasis be attained, although the line of demarcation is often quite mythical. Just as an engineering college is expected to train engineers for the construction field as well as for the research laboratory, so must its laboratories contribute both to the theory and the application of engineering principles. Problems in both of these categories will be sought as appropriate research projects for Georgia Tech's Hydraulics Laboratory.

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ELECTRONIC RESEARCH

Continued from Page 2

closely related to it by means of the necessity for development of use techniques, those research projects which employ the Georgia Tech electron microscope constitute concrete examples of the importance of electronic instruments and apparatus. The list of such equipment is long; to it might be added the Georgia Tech A-C Network Calculator, also described in recent issues of this journal.

Physical size of activities is no true measure of the importance of research in any field.

It may be of interest to note, however, that the Electronics Laboratories of the Georgia Tech Engineering Experiment Station occupy three buildings and several additional laboratories which have a combined floor space of 5,200 square feet, utilize laboratory and field equipment valued in excess of $300,000, and require, at present, the full-time services of 15 engineers and physicists and 4 technicians, in addition to 24 part-time faculty members, graduate students, and assistants.

The value of electronic research is recognized by all who employ its teachings in their work. Its importance to the national security is unquestioned. Georgia Tech's contributions to this field are part of its general program of research assistance to industry and government, services intended to aid in the development of Georgia, the South, and the country as a whole. All such services will be most effective only if their significance is understood, if the difficulties and occasional failures involved are properly evaluated, and if all those interested are continually aware of the necessity for a sane appraisal of science from a nontechnical viewpoint. The public should not be sold a glamorous "bill of goods," but instead should be told the true meaning of any given research project—either its direct implication or, if a fundamental study, the possible long-term value of this and analogous work.

RECENT STATION PUBLICATIONS

Continued from Page 12

tion is the required number of copies; when this is decided upon, intelligent economic selection can then be made from such diverse methods as typing, Mimeographing, Multilithing, hectographing, offset printing, etc. Consideration of illustrations and graphs must enter into the final selection; in addition to possible use of some of the above processes, methods employed here include photostating; photographic copy work; blueprint, Ozalid, and similar reproducing; and (in offset and regular printing) printing with screens. When the report is reproduced on single sheets, problems of assembly and durable binding must be considered. Finally, when such decisions are also concerned with such information service activities as the preparation of running card files and abstract bulletins, the reproduction techniques selected must involve a minimum of duplicatory efforts. A consideration of some of the economic and technical factors involved in a proper selection of reproduction techniques is presented in this paper.

Ingols, R. S. and Murray, P. E., *An Oxygen Consumed Test for Sewage*. State Engineering Experiment Station Reprint No. 23, 1948, 5 pages. 25 cents.

This paper presents a rapid analytical procedure for determining chemically the amount of oxidizable material present in sewage. A small aliquot of sewage is added directly to a small volume of a 1-1 mixture of phosphoric and sulfuric acids, plus some potassium dichromate, and the mixture is refluxed for 60 minutes in the presence of selenium. The amount of dichromate remaining after oxidizing the sewage is determined chemically; the oxygen consumed value is calculated by the difference in the dichromate present originally and finally; and this value is then corrected for the chlorine concentration of the sample.

SPECIAL REPORT

Weil, B. H., Bolen, Marjorie, and Sugarman, Nathan, *Literature Search on the Solvent Extraction of Oleaginous Materials*. State Engineering Experiment Station Special Report No. 26, 1948, 193 pages. $4.00 in U. S.; $4.50 foreign.

The solvent extraction of oilseeds has today become a commercial process of considerable significance, especially in regard to soybeans, cottonseed, and peanuts. Moreover, the tempo of present research and operational activities gives every indication that interest and attention will continue to increase. This being the case, this literature and patent search has been prepared in an effort to gather together an indexed, expanded bibliography of the pertinent literature, so that future work might benefit through use of and acquaintance with the existing data.

Some 502 literature abstracts and 394 patent digests are included in this book, which contains a 21-page detailed, alphabetical subject index. All phases of the subject are included, and special reference is made to by-products from the solvent extraction of peanuts.